US LHC ACCELERATOR PROJECT

*brookhaven - **fermilab** - berkeley*

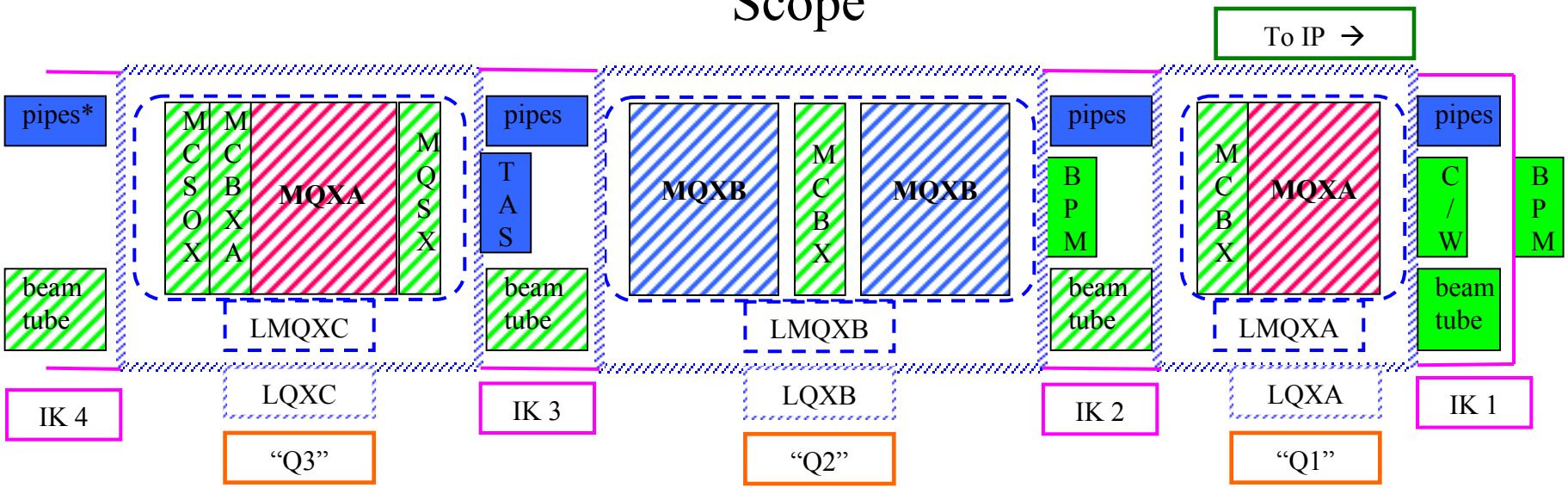
Status of the Fermilab - LHC Program

Jim Kerby

DOE Review of the US-LHC Accelerator Project

15 October 2003

Scope



Fermilab:

Designs, fabricates and tests the MQXB quadrupole magnet

Designs, fabricates, assembles and tests the LMQXx and LQXx Cryostats

Designs and procures portions of the Interconnect Kits, providing integration support for each

Provides Engineering and Test support for the DFBX

Provides Alignment and Energy Deposition Support for the inner triplet region

FNAL supplied

KEK supplied

CERN supplied

in production

Fermilab-LHC Status

Production is in full swing:

- 12+/18 MQXB complete; 3 / 9 LQXB Complete
- 5/18 MQXA delivered to FNAL; 0/18 LQXA/C complete
- 5/27 MCBX delivered to FNAL; 0/9 MQSXA delivered to FNAL
- 8 (+4) Production HTS lead pairs tested
- Instrumentation Bus Duct Ass'y underway

Recent technical results are a set back:

- LQXB01 test results good; LQXB02(MQXB03) good, LQXB02(MQXB04) not good.
- MQXB04 conductor limited, Q2 inner coil. Exact cause TBD.

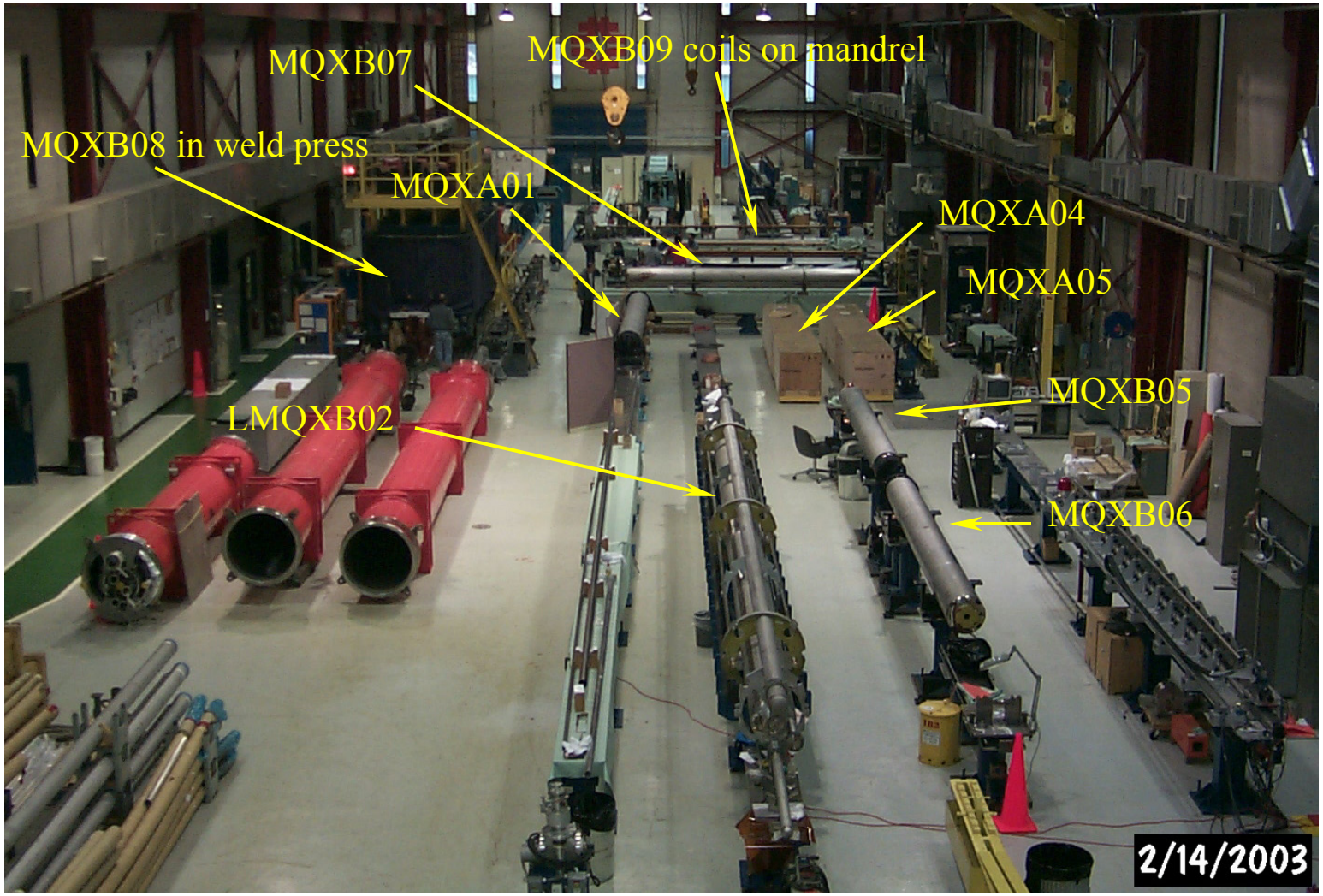
Cost variance unchanged since June 2002:

- LQXB02 will change this

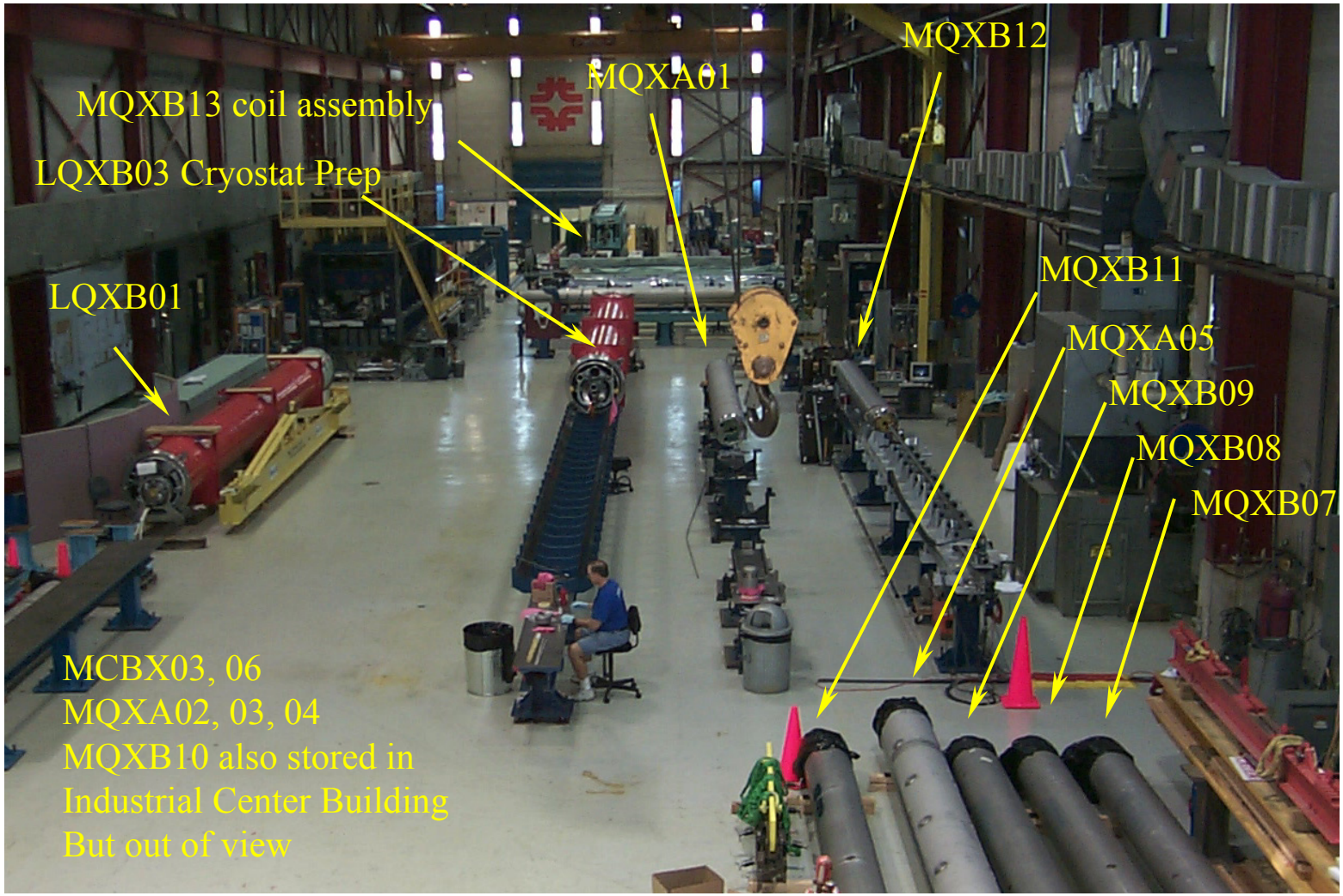
Schedule variance continues to grow:

- Corrector deliveries have driven final assembly, and will drive Q1/Q3 assembly schedule
- MTF will drive Q2 schedule
- Production effort juggling to accommodate correctors has hit schedule limit.

ICB last review



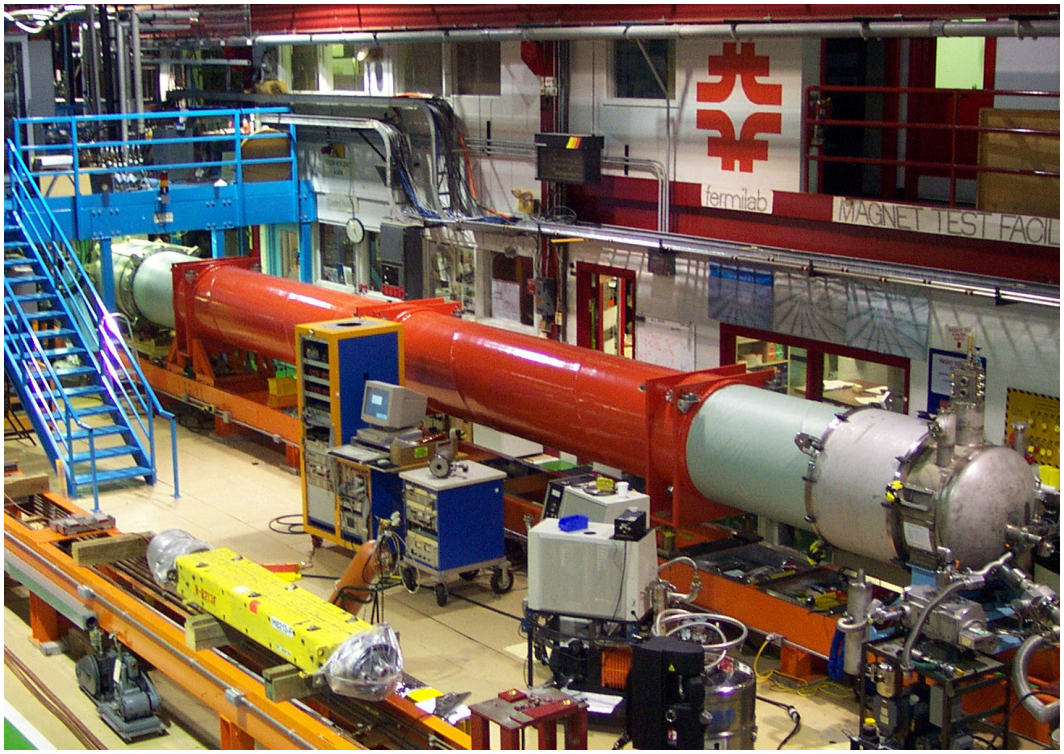
ICB last week



LQXB Testing

LQXB01 Testing Completed
- A very good magnet

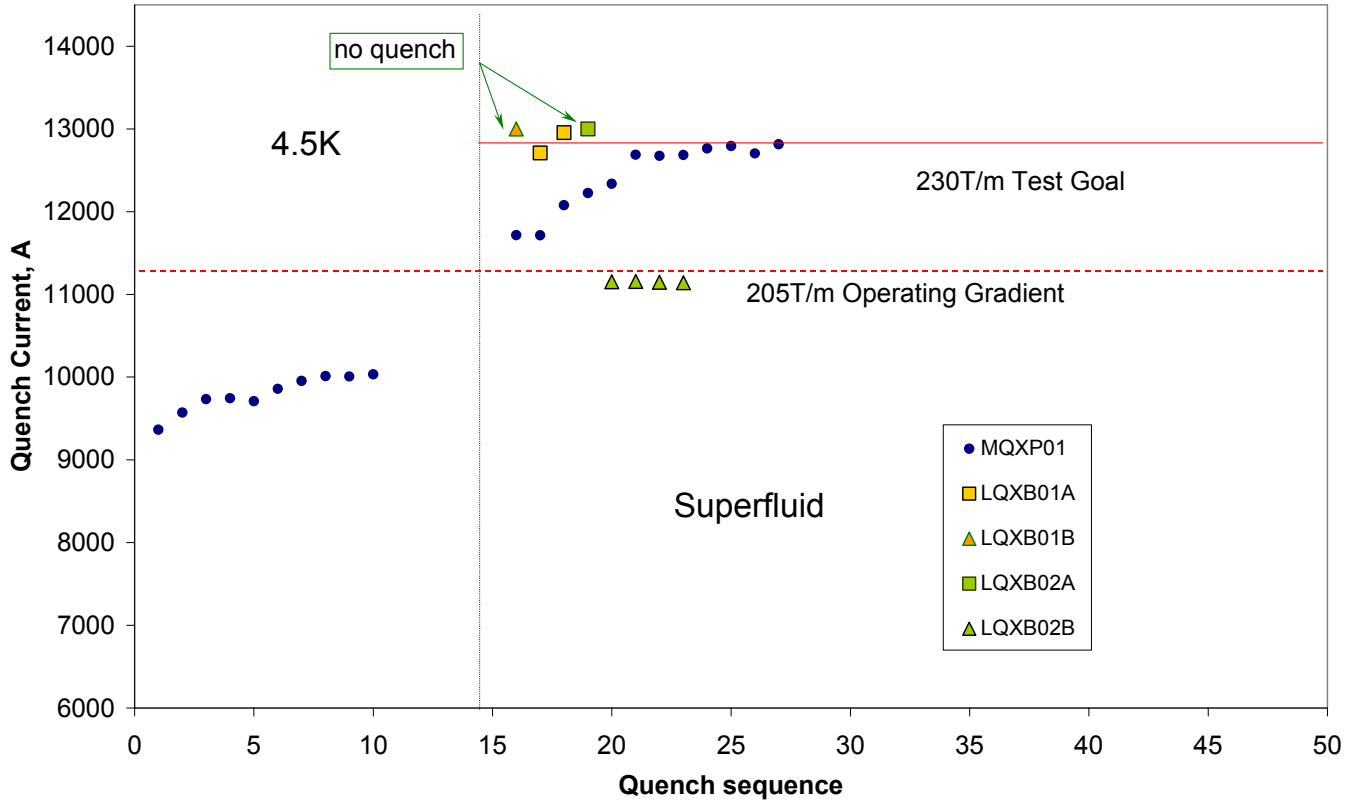
LQXB02 Testing Completed
- MQXB03 very good quench performance
- MQXB04 not
- Rebuild will be required



LQXB02 Quench Performance

MQXB03 follows in line w/ MQXB01 and 02…extremely good magnets.

MQXB04 has a hard limit at 11,150+/- 8A @1.9K

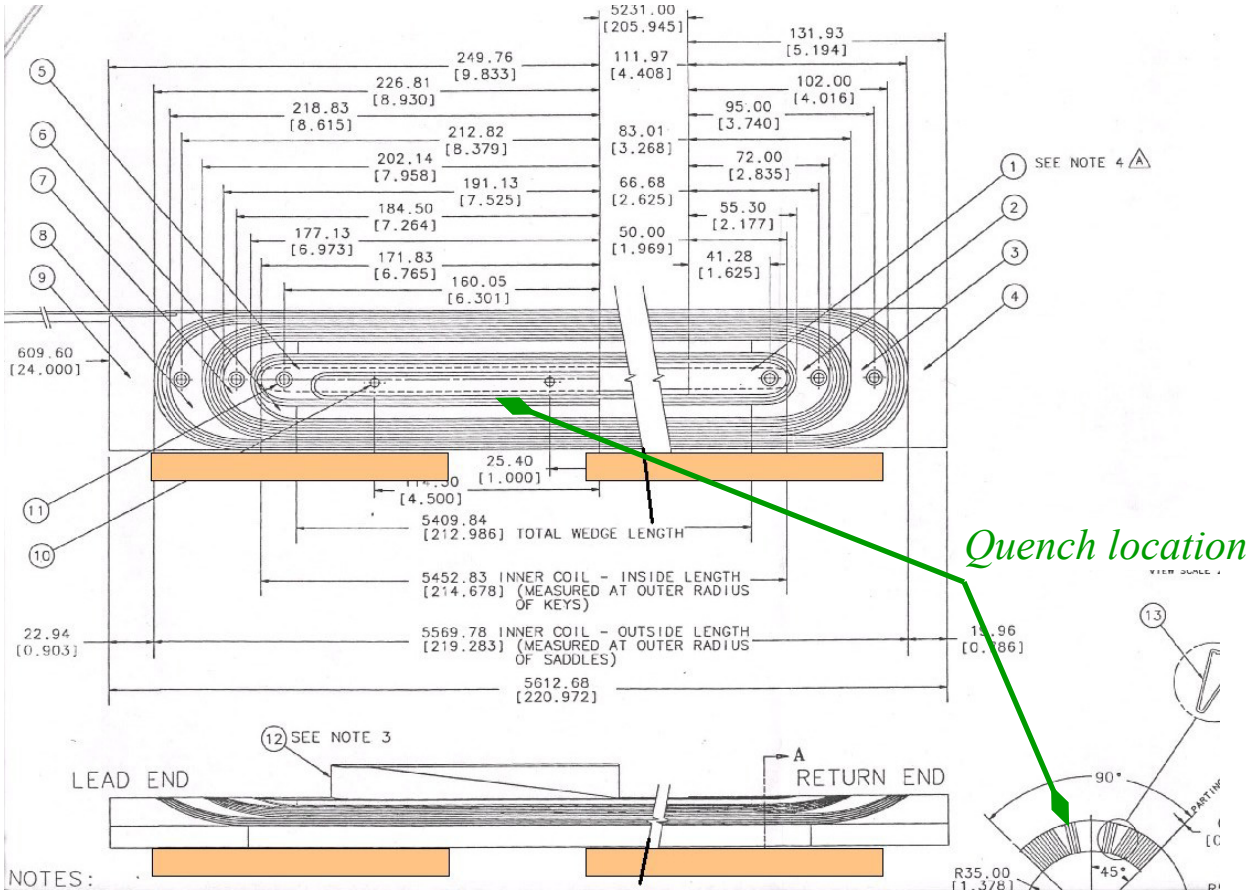


MQXB04 Quench Location

Quenches are located by voltage tap and quench antenna

Location is Q2, inner coil, above the wedge, in the straight section of the lead end

Behavior consistent with a local conductor limit



MQXB04 Data

MQXB04 made from same reel of cable as MQXB03, and 05

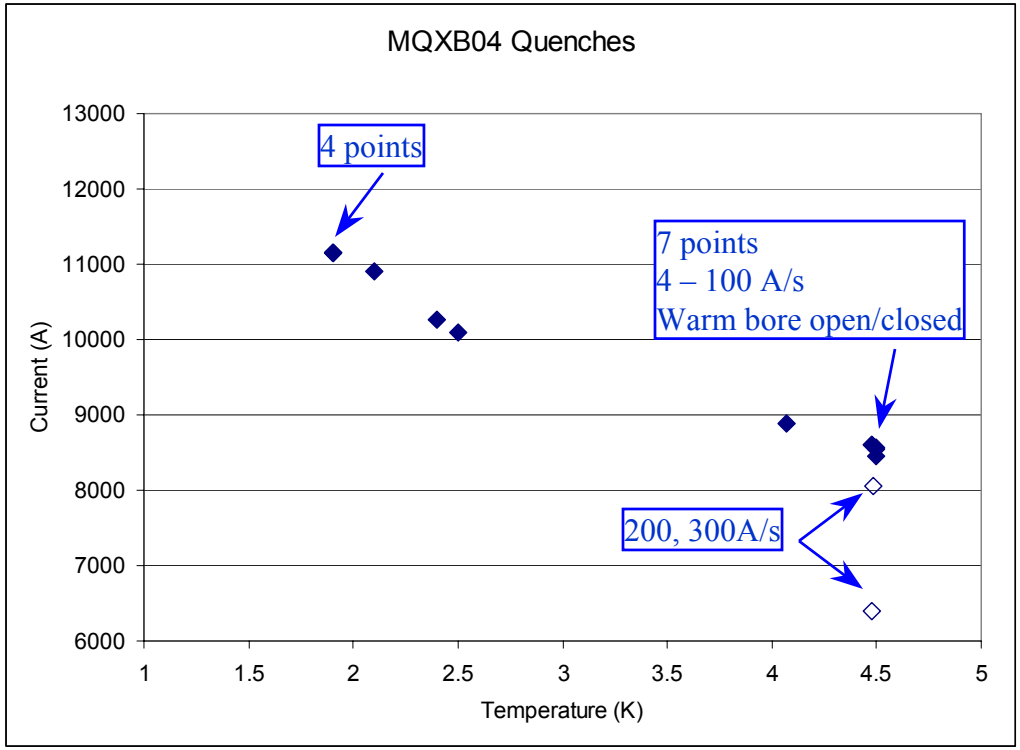
No ramp rate dependence

No dependence on heat load

Quench location the same except 300A/s point

Data show temperature dependence, not mechanical limit

Consistent w/ ~40% of strands in inner coil at this location not being superconducting



LQXB Plan Forward

Test LQXB03; Autopsy MQXB04

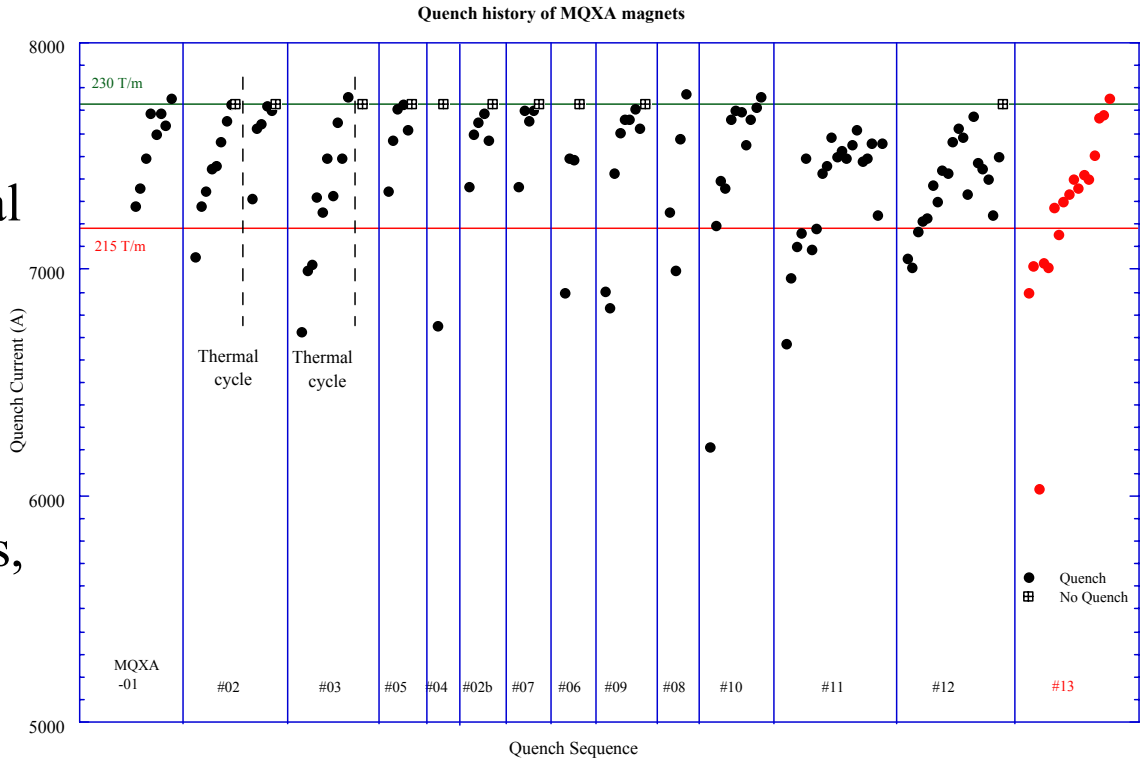
- Data suggest problem is not systematic
- LQXB03 already assembled—quickest way to success or at least generation of more data
- Quench location in MQXB04 localized, we know where to inspect
- Preserve MQXB03 during autopsy process

Rebuild LQXB02

- Utilize MQXB03
- Match with either rebuilt MQXB04, or MQXBP1
  - MQXB04 rebuild depends ultimately on autopsy findings and procedure and cost.
  - MQXBP1 use depends on potential voltage tap / beam tube interference
- Detailed technical and cost data being assembled

KEK Status (update)

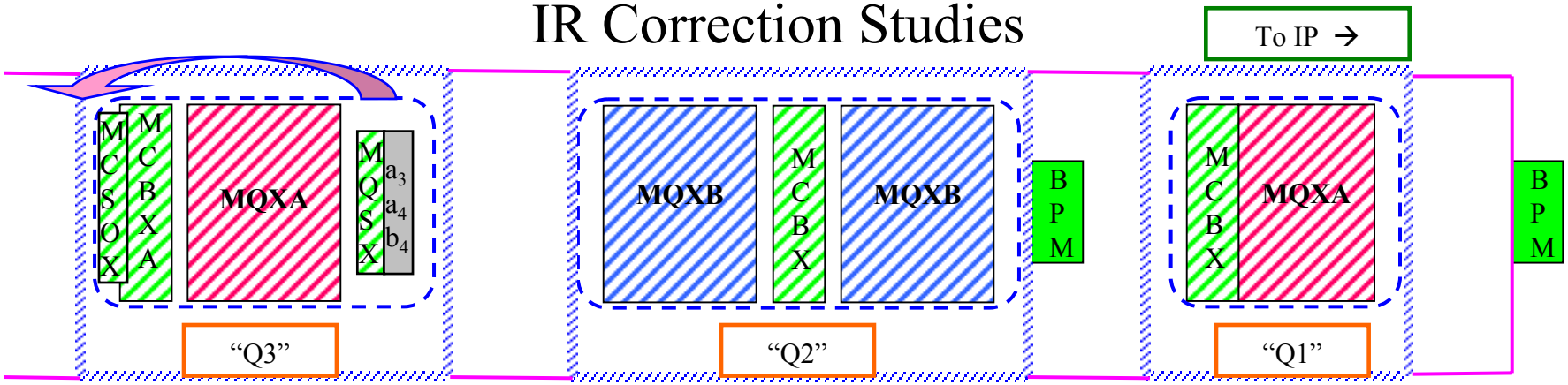
- First 5 MQXA deliveries in house
- 4 more MQXA deliveries week of Dec 8; additional 4 in Feb/Mar 2004
- MQXA14 test currently being completed
- We continue close contact (monthly teleconferences, emails, …).



CERN Status

- Q3 and Q1 tubes here, some Q2 Beam Tubes are here. Remaining Q2 tubes on way to BNL to be insulated.
- MCBXT001, MCBXS001, MCBX03, 04, 06 here.
- MCBX production units are delayed by testing at CERN.
  - Vendor producing 2 MCBX / month.
  - Contract changed to cold testing at CERN.
  - CERN tests currently limited to ~1 per month, working to improve to 1 every 3 weeks or 1 every 2 weeks. 2 tests per month just allow us to hit our schedule requirements.
- 1st MQSXA were delayed, but tested OK @ CERN in January / February 2003
  - Splitting of MQSXA into MQSX and MCSOX approved Aug 2003. 1st units of each tested at CERN and OK. These are not limited by the CERN test facility.
- Interconnect issues kept apace by frequent meetings, phone calls, and emails
  - Q1/IP, Q1/2 and Q2/3 interconnect layouts OK for all parties, in process of updating w/ finalization of new IR corrector layout.

IR Correction Studies



Studies last year showed the a3, a4, b4 inserts in MQSXA package were not well placed--CERN, US LHC iterated to find best technical and economical solution.

Option chosen:

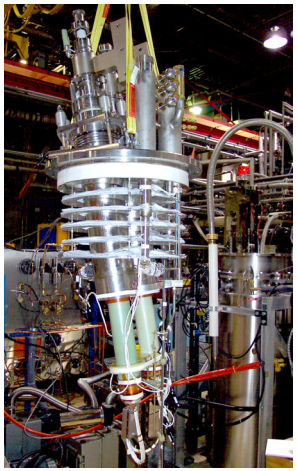
- Move whole just the non-linear layers to other end of Q3.
- Shift MQXA 300mm in Q3 vacuum vessel.
- Extend non-IP end dome 225mm, 75mm for additional offset of cold bore flanges in DFBX-Q3 interconnect

Final Approval in August 2003, redesign, release, and rework of parts underway

DFBX support

Fermilab is assisting in production oversight, acceptance tests, and assembly of the DFBX components

- 2-3 visits per month to Meyer tool, iteration & communication w/ LBNL & Meyer
- Warm & Cold acceptance tests of HTS leads.
  - 8 pairs accepted so far, 4 pairs rejected. 7 leads need rework before testing, and 17 leads await tests. We cold test 2-3 lead pairs per month.
- Production and delivery to Meyer of instrumentation bus ducts
  - Parts are in house, assembly underway, delivery expected at end of year.



Specifications, Acceptance Plans, Detail Designs

Considerable progress has been made on specifications, acceptance plans and formal sign offs since February.

- The LQXA and LQXC Functional Specifications, and the LQXA, LQXB, and LQXC Interface Specifications are in the CERN EDMS (or in the review process after revisions).
- The LQXB Acceptance Plan is being reviewed by CERN.
- Q2/Q3 interconnect and Q3 mechanical layout is being reworked based on change in magnetic layouts
- We have closure w/ CERN/TIS on safety documentation (2001); we are executing the agreement and they are kept informed of our status. TIS visited FNAL in June 2003.
- A CD bulk upload of 400 cryostat drawings is complete. Cold mass drawings to follow, as well as cryostat revisions.

Cost Performance

2 Fermilab related BCRs have been implemented since the last review:

- BCR52, DFBX Instrumentation Ducts (May 03, 56k$)
- BCR53, Q3 Move (July 03, 144k$, offset by reduction in cable testing at BNL)
  - CERN approval in parallel document LHC-LQX-EC-0002 (Oct 03)

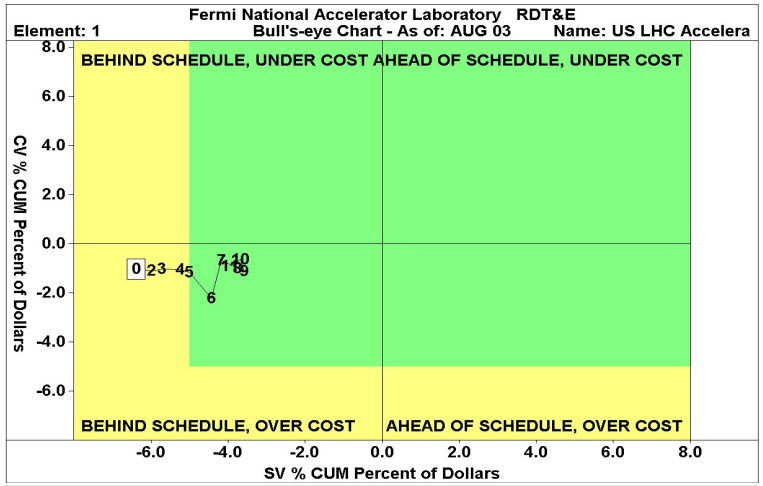
Re-baseline of the Fermilab effort ongoing

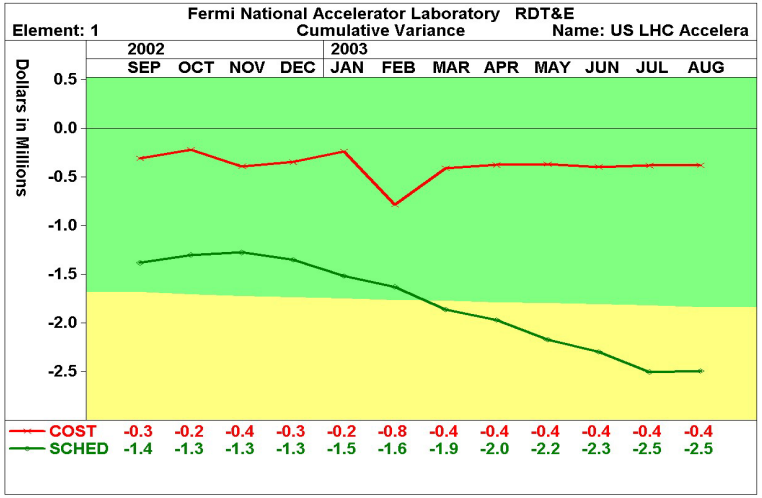
- Stable corrector delivery schedule largest single input, maybe now available
- Working version used and circulated for EAC, planning, etc.
- BCR preparation underway.

Cost / Schedule Performance

Cost variance has held stable for 18 months; schedule variance growing

- Production crew not ramped up as in original plan; held steady
- Schedule variance growing as total effort is under that originally planned
- Back log of final assembly / cryostat operations continues to grow, 2nd set cryostat tooling purchased and being installed
- LQXB02 test results reflected in Sep report; rework / rebuild estimates being assembled





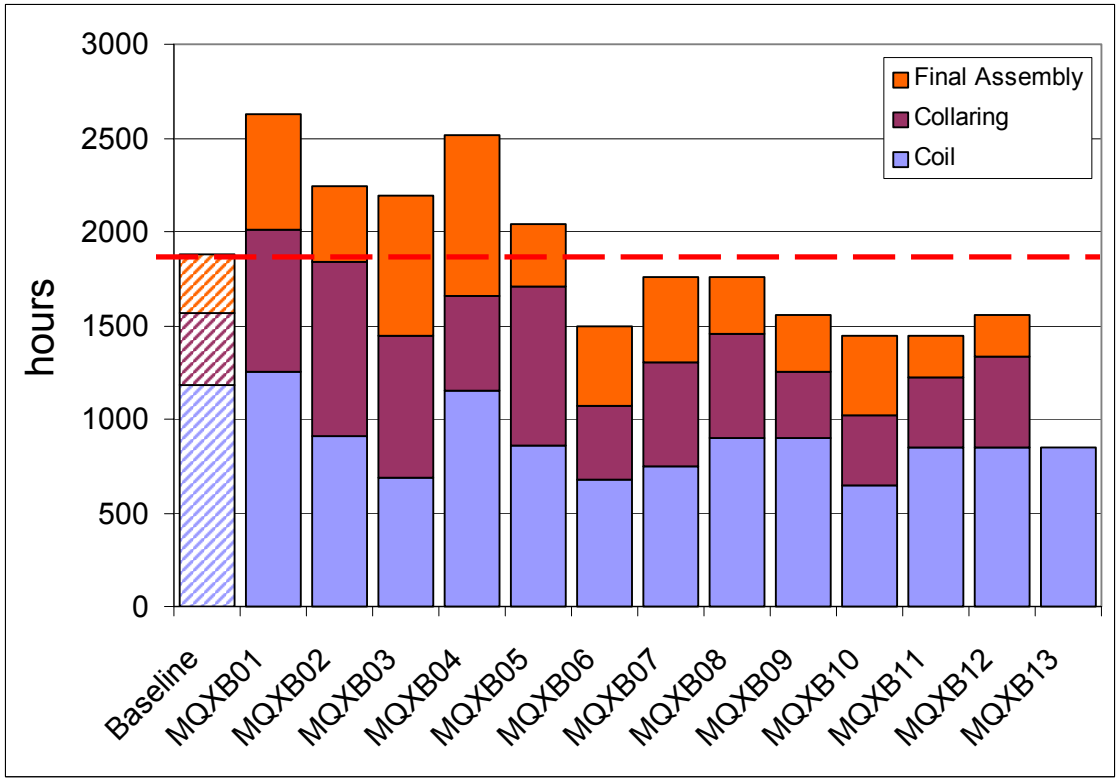
Cost Performance – Cold Mass Production Labor

Coil Production actuals continue to improve

Continued attention to production process and resolution of discrepancies shows results

Average hours for MQXB01-12 matches baseline

- Feb 03 MQXB01-07 avg overrun was 13%
- June 02 MQXB01-04 avg overrun was 27%



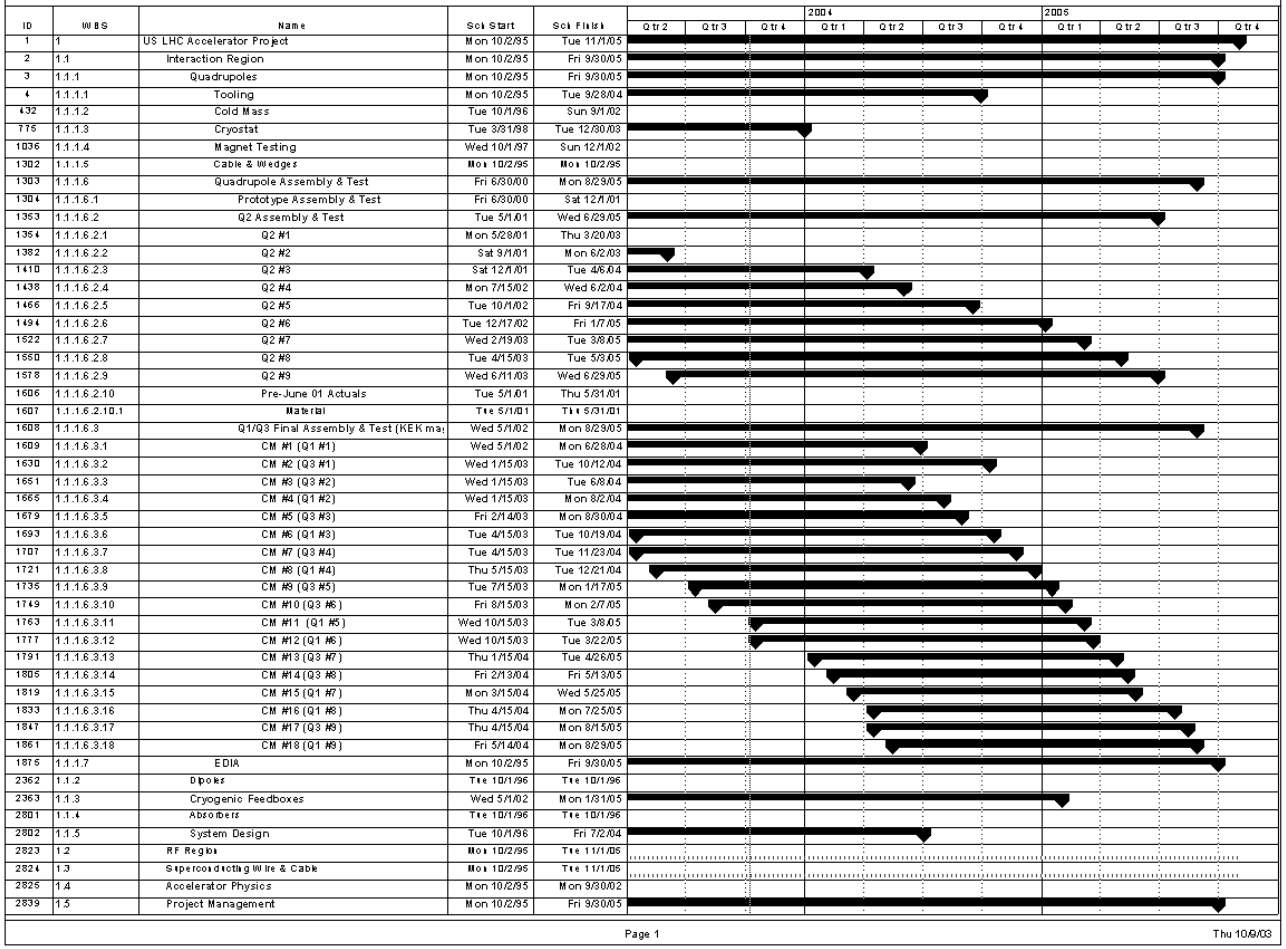
Schedule

Baseline Schedule is updated for EACs with new information as available

- Corrector schedule and cold tests are major drivers
- Limited latitude for any further juggling…program is relatively linear through both paths

PLEASE RETURN TO SHARON BY Wednesday 9 July
rev3 FNAL0307 JSK CERN sched wtooling.mpp

ID	WBS	Name	Sch Start	Sch Finish
1	1	US LHC Accelerator Project	Mon 10/2/95	Tue 11/1/05
2	1.1	Interaction Region	Mon 10/2/95	Fri 9/30/05
3	1.1.1	Quadrupoles	Mon 10/2/95	Fri 9/30/05
4	1.1.1.1	Tooling	Mon 10/2/95	Tue 3/2/04
432	1.1.1.2	Cold Mass	Tue 10/1/96	Sun 9/1/02
775	1.1.1.3	Cryostat	Tue 3/31/98	Tue 12/30/03
1036	1.1.1.4	Magnet Testing	Wed 10/1/97	Sun 12/1/02
1302	1.1.1.5	Cable & Wedges	Mon 10/2/95	Mon 10/2/95
1303	1.1.1.6	Quadrupole Assembly & Test	Fri 6/30/00	Mon 8/29/05
1304	1.1.1.6.1	Prototype Assembly & Test	Fri 6/30/00	Sat 12/1/01
1353	1.1.1.6.2	Q2 Assembly & Test	Tue 5/1/01	Wed 6/29/05
1354	1.1.1.6.2.1	Q2 #1	Mon 5/28/01	Thu 3/20/03
1382	1.1.1.6.2.2	Q2 #2	Sat 9/1/01	Mon 6/2/03
1410	1.1.1.6.2.3	Q2 #3	Sat 12/1/01	Tue 4/6/04
1438	1.1.1.6.2.4	Q2 #4	Mon 7/15/02	Wed 6/2/04
1466	1.1.1.6.2.5	Q2 #5	Tue 10/1/02	Fri 9/17/04
1494	1.1.1.6.2.6	Q2 #6	Tue 12/17/02	Fri 1/7/05
1522	1.1.1.6.2.7	Q2 #7	Wed 2/19/03	Tue 3/8/05
1550	1.1.1.6.2.8	Q2 #8	Tue 4/15/03	Tue 5/3/05
1578	1.1.1.6.2.9	Q2 #9	Wed 6/11/03	Wed 6/29/05
1606	1.1.1.6.2.10	Pre-June 01 Actuals	Tue 5/1/01	Thu 5/31/01
1607	1.1.1.6.2.10.1	Material	Tue 5/1/01	Thu 5/31/01
1608	1.1.1.6.3	Q1/Q3 Final Assembly & Test (KEK ma	Wed 5/1/02	Mon 8/29/05
1609	1.1.1.6.3.1	CM #1 (Q1 #1)	Wed 5/1/02	Mon 6/28/04
1630	1.1.1.6.3.2	CM #2 (Q3 #1)	Wed 1/15/03	Tue 10/12/04
1651	1.1.1.6.3.3	CM #3 (Q3 #2)	Wed 1/15/03	Tue 6/8/04
1665	1.1.1.6.3.4	CM #4 (Q1 #2)	Wed 1/15/03	Mon 8/2/04
1679	1.1.1.6.3.5	CM #5 (Q3 #3)	Fri 2/14/03	Mon 8/30/04
1693	1.1.1.6.3.6	CM #6 (Q1 #3)	Tue 4/15/03	Tue 10/19/04
1707	1.1.1.6.3.7	CM #7 (Q3 #4)	Tue 4/15/03	Tue 11/23/04
1721	1.1.1.6.3.8	CM #8 (Q1 #4)	Thu 5/15/03	Tue 12/21/04
1735	1.1.1.6.3.9	CM #9 (Q3 #5)	Tue 7/15/03	Mon 1/17/05
1749	1.1.1.6.3.10	CM #10 (Q3 #6)	Fri 8/15/03	Mon 2/7/05
1763	1.1.1.6.3.11	CM #11 (Q1 #5)	Wed 10/15/03	Tue 3/8/05
1777	1.1.1.6.3.12	CM #12 (Q1 #6)	Wed 10/15/03	Tue 3/22/05
1791	1.1.1.6.3.13	CM #13 (Q3 #7)	Thu 1/15/04	Tue 4/26/05
1805	1.1.1.6.3.14	CM #14 (Q3 #8)	Fri 2/13/04	Fri 5/13/05
1819	1.1.1.6.3.15	CM #15 (Q1 #7)	Mon 3/15/04	Wed 5/25/05
1833	1.1.1.6.3.16	CM #16 (Q1 #8)	Thu 4/15/04	Mon 7/25/05
1847	1.1.1.6.3.17	CM #17 (Q3 #9)	Thu 4/15/04	Mon 8/15/05
1861	1.1.1.6.3.18	CM #18 (Q1 #9)	Fri 5/14/04	Mon 8/29/05
1875	1.1.1.7	EDIA	Mon 10/2/95	Fri 9/30/05
2362	1.1.2	Dipoles	Tue 10/1/96	Tue 10/1/96
2363	1.1.3	Cryogenic Feedboxes	Wed 5/1/02	Mon 1/31/05
2801	1.1.4	Absorbers	Tue 10/1/96	Tue 10/1/96
2802	1.1.5	System Design	Tue 10/1/96	Fri 7/2/04
2823	1.2	RF Region	Mon 10/2/95	Tue 11/1/05
2824	1.3	Superconducting Wire & Cable	Mon 10/2/95	Tue 11/1/05
2825	1.4	Accelerator Physics	Mon 10/2/95	Mon 9/30/02
2839	1.5	Project Management	Mon 10/2/95	Fri 9/30/05



Page 1 Thu 10/9/03

Schedule

Deliveries to CERN are pushing close to milestones

Remaining schedule has 2 nearly equal critical paths:

- Delivery of tested correctors from CERN
- Cold testing of assemblies at Fermilab…we are developing a shorter quadrupole test plan to increase schedule float.

Completion of triplet assemblies as sets has to be attended to.

IRs Ready to Ship	IR	Ready to Ship Milestone	Float wrt Milestone
21-Apr-04	8L	10-Aug-04	111
25-Jun-04	2R	14-Sep-04	81
17-Aug-04	8R	25-Jan-05	161
04-Oct-04	1L	25-Jan-05	113
13-Dec-04	5L	7-Jun-05	176
27-Dec-04	5R	9-Aug-05	225
07-Mar-05	1R	30-Sep-05	207
09-May-05	2L	30-Sep-05	144
13-Jun-05	spare	30-Sep-05	109

Schedule – Corrector Impact

Current MS Project File			Current Estimated MCBX Test / Delivery			With Schedule Juggling			
Magnet	Corrector	Date	Corrector	End Test	@ FNAL	Magnet	@ FNAL	Test Install	End Test
LQXB01	MCBXS	22-Jan-02	MCBXS			LQXB01			
LQXB02	MCBXT	15-May-02	MCBXT			LQXB02		21-Feb-05	22-Apr-05
lqxa1	MCBX03	1-Aug-03	MCBX03			*lqxa1*		*30-Nov-03*	*26-Jan-04*
LQXB03	MCBX04	10-Jul-03	MCBX04			LQXB03		7-Oct-03	30-Nov-03
lqxb4	MCBX06	2-Sep-03	MCBX06			*lqxb4*		*27-Jan-04*	*16-Mar-04*
lqxc1	MCBXA08	1-Oct-03	MCBXA08	1-Oct-03	29-Oct-03	*lqxc1*	*29-Oct-03*	*17-Mar-04*	*11-May-04*
lqxb5	mcbx1	1-Oct-03	mcbx1	21-Nov-03	19-Dec-03	*lqxb5*	*19-Dec-03*	*12-May-04*	*29-Jun-04*
lqxc2	mcbx2	3-Nov-03	mcbx2	12-Dec-03	9-Jan-04	lqxc2	9-Jan-04	20-Feb-04	21-Feb-04
lqxb6	mcbx3	3-Nov-03	mcbx3	23-Jan-04	20-Feb-04	lqxb6	20-Feb-04	30-Jun-04	25-Aug-04
lqxa2	mcbx4	1-Dec-03	mcbx4	6-Feb-04	5-Mar-04	lqxa2	5-Mar-04	16-Apr-04	17-Apr-04
lqxc3	mcbx5	2-Jan-04	mcbx5	27-Feb-04	26-Mar-04	lqxc3	26-Mar-04	7-May-04	8-May-04
lqxb7	mcbx6	2-Jan-04	mcbx6	26-Mar-04	23-Apr-04	lqxb7	30-Apr-04	26-Aug-04	21-Oct-04
lqxb8	mcbx7	2-Feb-04	mcbx7	9-Apr-04	7-May-04	lqxb8	14-May-04	22-Oct-04	20-Dec-04
lqxa3	mcbx8	2-Feb-04	mcbx8	23-Apr-04	21-May-04	lqxa3	28-May-04	9-Jul-04	10-Jul-04
lqxb9	mcbx9	1-Mar-04	mcbx9	7-May-04	4-Jun-04	lqxb9	11-Jun-04	21-Dec-04	20-Feb-05
lqxc4	mcbx10	1-Mar-04	mcbx10	28-May-04	25-Jun-04	lqxc4	2-Jul-04	13-Aug-04	14-Aug-04
lqxa4	mcbx11	1-Apr-04	mcbx11	25-Jun-04	23-Jul-04	lqxa4	6-Aug-04	17-Sep-04	18-Sep-04
lqxc5	mcbx12	1-Apr-04	mcbx12	16-Jul-04	13-Aug-04	lqxc5	27-Aug-04	8-Oct-04	9-Oct-04
lqxc6	mcbx13	3-May-04	mcbx13	6-Aug-04	3-Sep-04	lqxc6	17-Sep-04	29-Oct-04	30-Oct-04
lqxa5	mcbx14	3-May-04	mcbx14	3-Sep-04	1-Oct-04	lqxa5	22-Oct-04	3-Dec-04	4-Dec-04
lqxa6	mcbx15	1-Jun-04	mcbx15	17-Sep-04	15-Oct-04	lqxa6	5-Nov-04	17-Dec-04	18-Dec-04
lqxc7	mcbx16	1-Jun-04	mcbx16	22-Oct-04	19-Nov-04	lqxc7	24-Dec-04	4-Feb-05	5-Feb-05
lqxc8	mcbx17	1-Jul-04	mcbx17	12-Nov-04	10-Dec-04	lqxc8	14-Jan-05	25-Feb-05	26-Feb-05
lqxa7	mcbx18	1-Jul-04	mcbx18	26-Nov-04	24-Dec-04	lqxa7	28-Jan-05	11-Mar-05	12-Mar-05
lqxa8	mcbx19	2-Aug-04	mcbx19	28-Jan-05	25-Feb-05	lqxa8	4-Mar-05	15-Apr-05	16-Apr-05
lqxc9	mcbx20	2-Aug-04	mcbx20	18-Feb-05	18-Mar-05	lqxc9	25-Mar-05	6-May-05	7-May-05
lqxa9	mcbx21	2-Sep-04	mcbx21	4-Mar-05	1-Apr-05	lqxa9	8-Apr-05	20-May-05	21-May-05

Fermilab LHC - Current Issues

Rebuild of LQXB02

- MQXB04 autopsy to be completed
- Options include
  - Rebuild MQXB04
  - Re-use prototype magnet
- Decision depends on technical findings and cost

Corrector Magnet Deliveries

- MQSXA; MQSX, MCSOX appear OK
- MCBX production is in full swing; deliveries delayed by tests at CERN

Redesign of parts from IR Correction Studies

- Correctors rebuilt at positioned, finalized in August 2003
- Redesign / rebuild of mechanical parts underway

Overall schedule

- 2 single unit test facilities drive schedule; limited margin available

Contingency Evaluation / Risks

There are three scenarios that might require a significant call on contingency:

1. Loss of a magnet assembly (i.e. failed test)
   - Previously estimated (May 2001 DOE review) as 360k$ (direct).
   - Current loss does not exclude another one in future
   - Re-estimate MQXB04/LQXB02 rework costs range 265k$ - 357k$ (direct)
2. Schedule extension due to delay in deliveries
   - Program extensions cost on the order of 40k$ per month; USLHC, CERN, Fermilab working to minimize impacts whenever possible
3. Schedule extension due to changes in design
   - Corrector layout modification, Q1 helium guard, change in alignment fiducials were not foreseen.
   - I do not see any on the horizon.

Summary

Fermilab-LHC program is in full production.

- Unit costs tracking well to baseline

LQXB02 results necessitate investigation and rework

- Determination of failure mode
- Scope of LQXB02 rebuild

Schedule is a major concern

- LQXB/A/C Cold tests at Fermilab
  - Test program under review, to be absolutely minimized to generate float
- MCBX/A Cold tests at CERN
  - Fermilab & CERN reviewing test program, shortening necessary to meet end date

We continue close communication with our colleagues and to be vigilant to ensure success through the end of production